DOCUMENT RESUME

ED 239 899 SE 043 855

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TITLE	Forces. Teacher's Guide. Units H1 and H2. ZIM-SCI, Zimbabwe Secondary School Science Project. Year 2.
INSTITUTION	Ministry of Education and Culture (Zimbabwe).; Zimbabwe Univ., Harare. Dept. of Curriculum Studies.
PUB DATE	May 83
NOTE	56p.; For study guides, see SE 043 853-854; for related documents see SE 043 827-859.
AVAILABLE FROM	Univ. of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Biomechanics; *Energy; *Force; General Science; Motor Reactions; Physics; *Science Activities; Science Education; *Science Experiments; Science Programs; Secondary Education; *Secondary School Science; Teaching Methods; Units of Study
IDENTIFIERS	Friction; Skeletal Systems; *Zimbabwe Secondary School Science Project

ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This teaching guide, designed to be read in conjunction with the related student guides, includes instructional strategies, lists of required materials, laboratory procedures, and other information for two units dealing with various aspects of forces and of forces associated with living things. Major areas investigated in the two units include: forces and changes they cause; measurement of forces; machines; power; and energy converters (Unit H1) and three main forms of support in plants; three main skeletal types in animals; limbs in animals as machines (muscles exerting a force on bone which acts as a lever); and protective functions of various skeletal parts (Unit H2). Each section in this guide corresponds to given sections in the student guides. (JN)

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ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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YEAR 2

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TEACHER'S GUIDE UNIT H1+H2

Forces

SE 043 855

UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE
2

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The following symbols which appear only in the Teacher's Guide are used to indicate important points for you the teacher.

Take note of an important point.

This symbol indicates a preparation of apparatus which should be done well ahead of time. Please read these notes carefully and carry out the instructions well in advance.

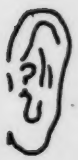
We have placed this symbol next to experiments where we feel there may be a possible danger. Please read the section carefully so that you know about the particular danger in that experiment. It would also be wise to refresh your memory on the appropriate safety or first-aid procedures described in the Zim-Sci Handbook.

This symbol appears next to activities which are not experiments but involve pupils in observation and perhaps collecting information. An example is the field trip.

The following symbols will be used to indicate the points in the lesson at which teacher activity is particularly important. These symbols also appear at the corresponding points in the pupil study guides.

Practical work. The necessary instructions for each experiment will be given to you when you see this symbol.

Written exercises for the pupils. If possible these should be put on the blackboard before practical work begins so that the pupils can see what to look for.



Teacher information. The pupils will need extra guidance at these points. The information they will need from you is given where you see this symbol.

This symbol appears at a point where it is necessary for pupils to think over what they have done in the past few lessons. Set aside a period for this review activity. Encourage the pupils to read over their notes and the study guide section which they have just covered. It may be helpful to ask them to write a summary too.

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ACKNOWLEDGEMENT: We are grateful for the considered advice we have received from the Regional Education Officers (Science) in the preparation in this unit.

MAY 1983

Aims of this Unit

At the end of this unit pupils should be able to:

1. Explain the connection between force and energy
2. Describe some ways in which forces act.
3. Name some substances which are elastic.
4. Name three forces which act at a distance.
5. Calibrate and use a force meter to measure forces.
6. Define the unit of force.
7. State the force of gravity.
8. Describe some advantages and disadvantages of friction.
9. Define the unit of work.
10. Describe some machines which make work easier.
11. Define the unit of power.
12. Explain why machines are useful.

Concept Development

If energy is "what makes things happen" then a force is the agent through which that purpose is achieved!

This unit begins by looking at familiar forces and what changes they cause. The concepts of a force having magnitude and direction are emphasised. These concepts lead into the idea of opposing and then balancing forces.

Unbalanced forces lead to the concept of acceleration and a first look at the concept of momentum.

Forces which can act at distance are introduced with simple magnetic and electrostatic experiments. The force of gravity is also classified here as a force which acts at a distance and the distinction between mass and weight is underlined.

The second part of this unit begins with the measurement of forces.

A simple spring forcemeter is introduced as a measuring instrument and pupils calibrate it in terms of gravitational forces. In order to do this pupils are introduced to the Newton as the unit of force. Pupils use the calibrated forcemeter to measure various mechanical forces and go on to investigate the nature of frictional forces. The study of friction concludes part II.

Having established the concept of a force and given pupils some experience in measuring forces, Unit H_1 now concentrates on the links between force of energy in developing the concept of work. A definition for work arises out of the discussion of a number of simple experiments and activities, and leads on to the definition of the Joule as the unit of work and energy.

Machines are introduced as devices which make work 'easier' by reducing the rate at which the work is done. Exploring this concept through a number of experiments with simple levers and pulley systems clarifies the easier work' concept and lays the foundation for the introduction of power and the definition of the Watt.

A simple experiment measuring muscle power and a comparison of the power available from various common energy units concludi the unit.

N.B.

Look up (P) signs in Unit H_2 and start collecting bones and boxes now.

Introductory discussion: the purpose of this discussion is to help pupils realise that forces are familiar things. It's worth getting pupils to describe the forces being used in the activities illustrated on Page 4. Questions like "why do you need to use a force" or "what are the forces being used against?" will begin to make pupils think of forces acting in pairs a concept which is developed a little later.

Try to keep pupils aware of the connection between force and energy by asking such questions as "how will the girl feel if she has to lift and carry fifty bundles of wood home before she goes to school especially if she has no breakfast first!" Why will the mother get tired after carrying the baby a long time?

Experiment 1 Page 5

Although a brick on a string is described as the object to be lifted, any reasonably heavy object will do. For instance the same result (muscle fatigue) could be achieved by asking pupils to lift up their chairs at armslength several times.

Experiment 2 Page 6

Make sure you count out the rubber bands and count them back in again. Pupils enjoy playing with them!

If you have a bright class you can try an additional experiment with the rubber bands which helps to establish the connection between forces and energy.

If a rubber band is stretched suddenly while placed against a lip (as shown in the diagram) it will feel quite warm. The increase in temperature is the result of the work being done in stretching the rubber being converted into heat through friction and rearrangement of the rubber particles. If this extra heat is allowed to escape into the air so that the stretched band is once more at room temperature, it will cool

as when the band is allowed to suddenly return to its normal length. In this case the energy needed to rearrange the rubber particles is taken from the heat energy of the rubber.

Activity 1 Page 8

Provide from the Zim-Sci materials kit the following:-

2 springs

4 metal strips

Plastic strip

Perspex strip

Sponge

N.B. Pupils should be very gentle and not damage the materials, straighten them out afterwards.

There are two forces at work:-

pushing and pulling

Even when twisting there are two forces present working in opposite directions.

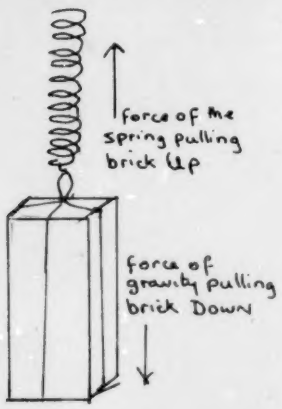
Exercise 1 Page 8

1. What happens to a piece of rubber when it is pulled?
2. Write down three other substances which behave like rubber when they are pulled or pushed.
3. What do we call materials which have this property?
4. Where did the force and energy used to stretch the rubber bands in Experiment 2 come from?
5. If we stretch a piece of rubber so that it is 100 mm longer than it was originally, how big must the force be to stretch it so that it is 200 mm longer.

6. The picture shows a brick hanging on the end of a spring. Draw the picture and show with arrows any forces which are there. Why is the brick not moving?

Answers to Exercise 1

1. When a piece of rubber is pulled it stretches/gets longer/ changes its shape.
2. Plastic, steel springs, perspex, sponge block .
3. Elastic.
4. The force came from muscles, the energy from the food eaten.
5. The force used must be twice as big.



6. One arrow points downwards (the force of gravity) one arrow points upwards (the elastic force in the spring), The brick does not move because the forces are balanced.

Experiment 3 page 8

The purpose of this experiment is to extend the concept of elasticity to gases. Pupils may find this idea surprising. Encourage them to think of what is happening to the gas in terms of what they discovered about particles in Unit C_2.

Exercise 3

Where did the push and pull forces come from, and at which point was there a balance of the forces when you:-

a) Forced the handle in and then let go

b) Pulled the handle out and then let go

pages 9 & 10

Exercises 2 and 3. This explanation covers both exercises.

In a gas, like air, the particles are moving about in all directions at very high speeds, bouncing off the walls of the container. The continual effect of many millions of particles hitting the walls creates 'pressure'. When the handle of the syringe is pushed in, the volume of the air is

8 decreased and so the number of particles hitting the walls is greater and so the pressure increases. When the force being used to push the handle in is removed the extra pressure pushes the handle out again until the pressure of the particles inside is again equal to the pressure created by the free air particles on the outside of the syringe.

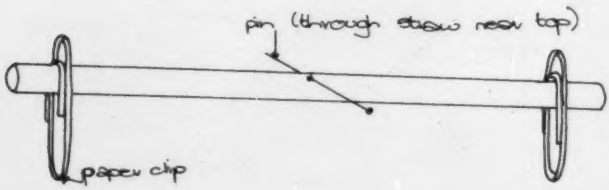
When the handle is pulled out and then released the opposite happens. As the volume gets bigger the number of particles hitting the inside walls become fewer and the pressure less. When the handle is released the higher outside pressure pushes the handle in again until the pressures are equal once more.

Experiment 4 page 10

Empty matchboxes are useful laboratory items. Try to get pupils into the habit of picking them up and bringing them to school!

In balancing the straw pupils will find the experiment easier if they put the pin through the straw nearer the 'top' of the horizontal straw.

In using the paper clips as small weights it is important that pupils use the small loop of the clip so that it fits tightly on the straw and hangs down below the straw.



At this stage it is not intended to teach children the formal 'law of moments'. But pupils should realise that the further the clip is from the pin the more turning force it causes and if two clips are placed at the same distance from the pin on one side, the turning force is doubled.

N.B. (pivot = turning point)

They should also realise the straw becomes level when the opposite turning forces are 'balanced'. Brighter pupils may notice that two clips on one side can be balanced by one clip at twice the distance on the other side.

Exercise 4 page 12

1. When a clip is on the straw it makes a turning force which tries to turn the straw around the pin. How can you make the turning force bigger?
2. What makes the straw level when it has clips on both sides?
3. Which force is involved in these experiments?

Answers to Exercise 4 page 12

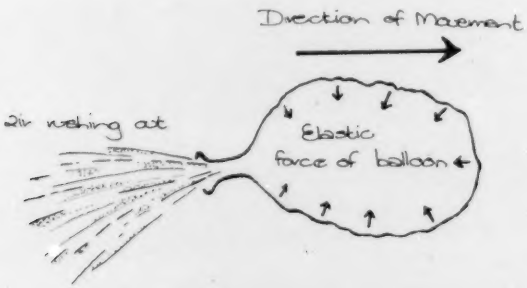
1. Use more than one clip or move the clip further away from the pin(pivot).
2. The turning forces are equal and balanced.
3. The force of gravity on the clips.

Experiment 5 page 13

The flying balloon. Pupils enjoy this experiment and since it illustrates some very important concepts it is worth doing more than once!

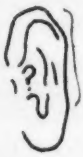
The balloon is elastic and when it is blown up air is forced in (by muscles in the chest) increasing the air pressure inside. The extra air pressure is balanced by the elastic squeezing force in the skin of the balloon. When the balloon is suddenly opened the extra air rushes out and the balloon skin shrinks back to its normal size.

The air rushing out behind the balloon pushes the balloon in the opposite direction.



This is the principle behind the rocket and jet engine.

N.B. The balloon does not fly away because of the air rushing out and hitting the outside air. This is incorrect. In fact a rocket engine works best in a vacuum when there is no air outside to get in the way of the gases rushing out of the engine.



Experiment 6. The Match Experiment page 14

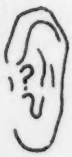
The match suddenly burst into flame and the rush of hot gases out of the small holes in the aluminium foil causes the matchhead and foil to fly right out of the evaporating dish. Pupils should not stand too near their burners - some hot match heads may hit their faces!

The force is similar to the force in the balloon experiment. The rapidly expanding gases push the matchhead and foil in the opposite direction.

The energy which causes this to happen is contained in the chemicals on the matchhead as potential energy changed into heat by the chemical reaction which produces the gases.

The concepts of acceleration and momentum Page 15

Once again it is not intended to make a formal definition of these concepts but in the activity with the rolling tin and the subsequent discussion we hope you will begin to establish the basic ideas.



Acceleration, that is changes in speed (more correctly velocity) can be illustrated by asking children to tilt their desks slightly and observe gradually increasing velocity of the tin as it rolls across the desk. It is worth helping them to realise that the force causing this acceleration is part of the force of gravity . The part (of the force of gravity) gets bigger and bigger the more the desk is tilted. When the tin falls vertically the whole force of gravity accelerates it. (The push with the finger which started the rolling obviously had no further effect.)

Once children are convinced that a force is always involved in an acceleration, whether it is a 'speeding up' or a 'slowing down and stopping', then the next step is to suggest that the force required will be bigger if the moving object has a larger mass. Thinking about the example of the moving drum of water will help to convince pupils of this. Perhaps you might let them roll empty and then water filled plastic bottles across the desk and observe the increased force needed to get the full bottle rolling and accelerating (more tilt of the desk) and the extra force needed to stop it. The combination of velocity and mass is called the momentum of an object. Changing the momentum of something usually means changing the velocity which must mean a force is involved.

Exercise 5 page 16

1. A motor car which changes its speed from 10 km/h to 20 km/h is .....
2. A cyclist who slows down and stops is .....
3. Explain how forces are involved in the changes described in questions 1 and 2 and where the energy for these forces come from.
4. A heavy lorry travelling at 50 km/h has more ..... than a small car travelling at the same speed. The lorry has more ..... and will need a ..... force to stop it.

Answers to Exercise 5

1. Accelerating. (positive acceleration)
2. Accelerating. (negative acceleration)

   N.B. A bright class can be introduced to the idea of positive acceleration (question 1) and negative acceleration (question 2).

It is worth pointing out that acceleration can happen in two different ways. 'Speeding up' which is called positive acceleration and 'slowing down' or negative acceleration. Sometimes negative acceleration is referred to as deceleration. The more scientific terms are positive and negative acceleration.

3. The motor car accelerated because of the force generated in its engine. The energy comes from the burning of the petrol.

Chemical potential energy ⟶ heat ⟶ kinetic energy

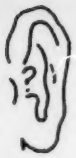
Petrol ⟶ { burning in engine / causing force by / expanding gases } ⟶ moving car

The cycle slows down and stops because of the frictional force generated by the brake blocks rubbing against the wheels. The energy lost by the slowing cycle is changed into heat on the brake blocks.

Kinetic energy ⟶ heat energy

Moving cycle —(frictional force)⟶ warming brake blocks

4. Momentum, kinetic energy (or momentum) larger.



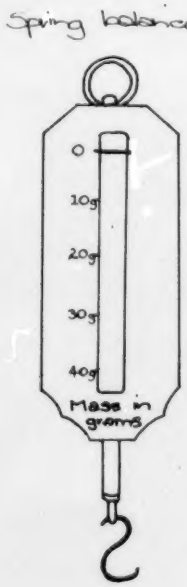
Forces at a distance Page 17

Pupils already have considerable experience of the force of gravity. The press up exercise is used to emphasise that the force of gravity is always there and another force, in this case generated by the muscles, must always be used to overcome it. The important point to establish at this point is the difference between mass and weight. (See page 18 in study guide.)

Experiments 7 and 8 - as in pupils guide

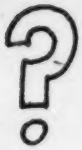
Exercise 6 Page 20

1. Name three examples of a force which acts at a distance.
2. How would you convince someone who is blind of the existence of the force of gravity?
3. Sometimes you will see a scale like the one drawn in the picture. What is completely wrong about it?



Answers to Exercise 6

1. Force of gravity, magnetic force, electrical force.
2. This is an open ended question which is meant to stimulate the children's imagination. There will be many different answers. They should say something about handing the blind person objects of the same size but different mass to feel the different gravitational force. They might also bring out the fact that this force is always in the same direction - downward.
3. The instrument drawn is a spring balance - still very common as a weighing device. It reacts to the force of gravity and so does not actually measure mass. But since the force of gravity is approximately the same all over the earth it can be calibrated in mass units and this is often done. It actually measures the force of gravity. (The force meter introduced in the next section is based on this principle.)



Answers to How much do you know (Part 1) Page 20

1. When a force is used, energy is needed.
2. Forces, like energy, cannot be touched but can be identified by effect or action
3. A force is needed to move an object.
4. A force is needed to stop a moving object.
   The greater the mass or momentum of an object the greater the force needed to stop it.
5. Force can speed up or slow down the movement of objects
6. A force has a direction which can be represented by an arrow.
7. Push and pull forces act in pairs in opposite directions.
8. Push and pull forces may change the shape of an object.
9. Substances which return to their shape after stretching or squeezing are said to be elastic.
10. Air is an elastic substance, so is steel or rubber or plastic and a spring.
11. Equal forces acting in opposite directions are called balanced forces.
12. When one force is greater than another the forces do not balance.
13. The force with which the earth pulls things is called the force of gravity.
14. Weight is a force. The weight of something is the force with which the earth acts on that thing.
15. Two forces which act at a distance are gravity, magnetism, electricity (any two). They make things move without anything touching them.

Part II Measuring force.

The measurements which the children will make in parts II and III are not intended to be very accurate. They are important because they establish the concept of force as a quantity and lead to familiarity with the Newton as the unit of force.

Page 21 In the preliminary discussion on measuring forces you may find children suggesting using elastic bands stretching as a way of measuring force. Some may suggest lifting a larger and larger mass with one finger. Accept both suggestions, but point out that in both cases, what is being done is a comparison. The 'finger force' is being compared with the force in an elastic band or with the force of gravity acting on various masses. This is the concept which we want pupils to grasp in thinking about the forcemeter.

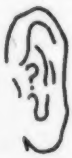
Experiment 9 (page 22) is a quantitative extension of this idea. The pupils are comparing gravity forces on various masses with the stretch of the spring. It is important for the pupils to realise that in this comparison no further stretching happens when the force generated in the spring is equal but opposite to the force of gravity. So the amount of stretch is a measure of the force in the spring and is therefore a measure of the force of gravity.

The Newton

The Newton is introduced as the unit of force by illustration using the force of gravity as an example.

The force of gravity is stated as 10 Newtons per kilogram. In fact the force of gravity varies from about 9.75 to 9.85 Newtons per kilogram depending on whereabouts on the earth's surface the measurement is made (it depends on the amount of mass directly under the instrument) but 10 N/kg is sufficiently accurate for pupils at this stage and also for O-level.

Discussion



Since the pupils have seen how the stretching of a spring is related to the force it generates and can see that the force-meter contains a spring it is only a short step to working out how to calibrate the forcemeter. Make sure the pupils realise that the forcemeter can be used to measure pull and push forces.

Experiment 10 page 24

If you have more than one class it will require a little organisation to give all the pupils some experience of calibrating the forcemeters. If you have two classes perhaps working in larger groups will enable 10 to be calibrated by one class and 10 by the other. Another suggestion is to allow more than one scale to be marked on the instrument. This could lead to considerable argument as to which is accurate! A third possibility is to allow one class to calibrate the instruments to the halfway mark (Ten 5g masses equivalent to a force of 0,5 N) and the other class to carry on for 0,5 N to 1,0 N.

Experiment 11 page 25

Object	Push or pull	Amount of force needed to start movement

Exercise 7 page 25

1. Write a short paragraph describing how the forcemeter works
2. How would you change it to measure forces twice as strong?

Answers to Exercise 7.

1. (see introduction to this section of T.G.).
2. Use a stronger spring or two identical springs

Activity 5 page 25

Pupils are gradually becoming aware that all changes in motion; from rest to movement, from faster to slower and from slower to faster all involve forces. When they realise this the existence of frictional forces becomes obvious.

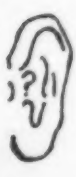
Experiment 12 Page 26

If it is inconvenient to use the kit box for this experiment any reasonably uniform solid with a mass of 1 kg or more will do. A clean brick would be excellent! The purpose of this preliminary experiment is to begin to establish the idea that frictional forces are dependent on the surface areas in contact and the mass and hence force of gravity.

N.B. Some schools have plastic bags instead of kit boxes. Try to collect cardboard boxes for use in this and further experiments. Shoe box containers are ideal.

Experiment 13 Page 28

This is a quantitative repetition of the Experiment 12. If something is used other than the kitbox be sure to test the experiment before the lesson to make sure the range of frictional forces is within the 0-1 N range of the forcemeter! Pupils should use another table like that given in Experiment 11.

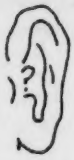


Methods of reducing friction

Any way of making the surfaces smoother or adding lubrication between them e.g. oil will reduce the frictional forces. Any way also of reducing the area of contact like using the mounted needles will also reduce friction.

Frictional forces and energy

Frictional forces are involved in the change of kinetic energy to heat energy. Rubbing hands together is a simple example of this.



Friction and the bicycle

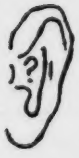
The bicycle is an ideal machine for illustrating many aspects of friction both useful and disadvantageous. The ball bearings used in the wheels and pedals mean that the surfaces rubbing together are reduced to a minimum as the balls roll instead of rubbing.

Exercise 8 page 30

List two parts of the bicycle where frictional forces are found and explain how the friction is reduced.

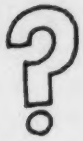
e.g. wheel axles or pedal axles contain ball bearings.

chain links are oiled.



Should friction always be reduced Page 31

Discuss with the children how brakes and tyres are designed to increase the amount of frictional force they generate.

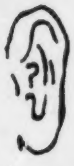


Answers to How much do you know Part II Page 32

1. An instrument which measures force is called a forcemeter.
2. A forcemeter can be calibrated by hanging 5g masses on it two at a time and markingthe scale in 0,1 N intervals.
3. The standard unit of forces is a NEWTON.
4. The force of gravity on a mass of 1 kg is about 10 N.
5. When two surfaces rub against each other a frictional force is produced.
6. Friction makes it difficult for things to move.
7. Friction forces produce heat energy when they act.
8. Friction can be reduced by the use of grease, oil or ball bearings.

Part III Doing Work

In this third and final part of the unit we are linking the concept of force with the concept of energy. As we said in the beginning of this guide, if energy makes things happen then force is its agent or 'action maker'. Hence "Forces in Action".



In the initial discussion we want to begin to establish the idea that the amount of energy depends on both the size of the force and the distance over which it acts.

Exercise 9 Page 35

Describe the work being done in each set of pictures. Make sure you mention what force is being used, what force it is acting against, how far the force acts , where the energy is coming from and in what form it ends up. You might like to estimate who does the most work in the single action illustrated and who does the least!

Answers to Exercise 9

In the first set of pictures the boy is using the forces of his muscles to lift his body against the force of gravity a distance of 0,5 m. The energy comes from the food he eats and is converted partly into potential energy when he is standing on the chair and partly into heat in his muscles.

The girl is using her muscles to lift the bucket of water a distance of 1,5 m onto her shoulder. She is also acting against the weight (force of gravity on the mass) of the bucket and water. The energy changes are also the same.

The man is lifting bricks a distance of 1 m. The forces involved and energy source being the same as before. Brighter pupils may point out that the way the man is using his food energy is not very efficient since each time he lifts a brick he also lifts the upper half of his body. He probably uses more of his energy on himself than in building the wall!

For the single action illustrated the girl is probably doing the most work since she has to overcome quite a large force and moves it over the largest distance.

Exercise 10 Page 36

Actual amount of work done in each example. This is obviously based on estimate of the mass in each case.

(a) Boy lifting himself. Mass of boy estimated at 30 kg

Therefore force of gravity on his body

= 30 x 10 = 300 N

Distance force of gravity worked against

= 0,5 m

Therefore work done by muscles

= 300 x 0,5 = 150 Joules

(b) Girl lifting a bucket of water. A normal bucket holds about 10 litres (2 gallons in old units). A litre of water has a mass of 1 kg therefore mass of water lifted = 10 kg + mass of bucket say another 1 kg. Total mass = 11 kg.

Force of gravity to be overcome = 11 x 10 = 110 N.

distance moved = 1,5 m.

therefore work done by muscles = 110 x 1,5 = 165 Joules

(c) mass of a brick approximately 2 kg

therefore force on it = 2 x 10 = 20 N

distance lifted = 1 m

therefore work done in lifting one brick (ignoring work on own body!) = 20 x 1 = 20 Joules.

Experiment 14 Page 36

Table for observations:

Object	Action	Amount of Force to be Overcome	Distance Moved	Work Done
e.g. Matchbox filled with sand. etc.	lifting against force of gravity.	1 N (measured by pupils)	2 m?	2 Joules

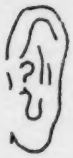
N.B. 'sliding'experiments are working against the force of friction.

Exercise 11

Pupils should now be in the habit of writing a full account of each experiment they do.

Work should be less if friction is reduced

Making work easier



The purpose of this discussion is to reinforce the concept of work done or energy converted to another form depends on both the size of the force to be overcome and the distance over which the action takes place.. Pupils should notice that as a consequence the force needed to push the door is less if it is pushed near the edge instead of near the hinges although the amount of work done is the same!

Exercise 12 page 38

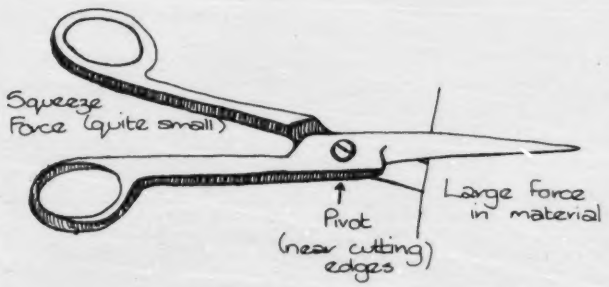
How did you vary the amount of force needed in each of these simple actions?

Answer: the amount of force depended on the distance from the point of action of the force being overcome.

Machines

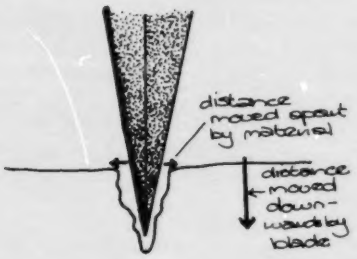
1. The pliers and scissors create a large force near the working end because the muscle force is exerted quite a long way from the pivot point. Of course the distance over which the larger force acts is much smaller than the distance moved by the muscle forces otherwise we would get more energy out of the machine than we put in, which is impossible! Energy cannot be created

This is an interesting discussion point to talk over with the pupils. Refer back to unit B.



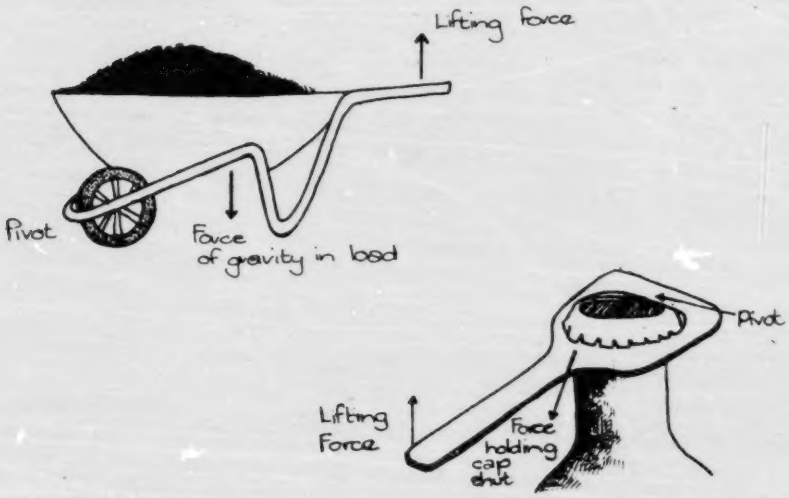
2. The scissors and knife cut because of another "force enlarging effect."

Magnified cross section of knife or scissor blade.



As the sharp end of the wedge shaped blade is pushed against the material it is cutting it causes the material to be pushed away on either side. Because the blade is a narrow wedge shape the distance moved sideways by the cut material is much less than the distance moved downwards by the force acting through the blade. This greatly enlarges the force in action so that it can overcome the particle forces holding the material together.

The bottle opener and wheel-barrow are examples of a different type of lever.

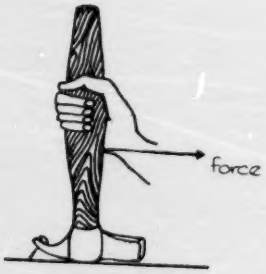


Other simple machines.

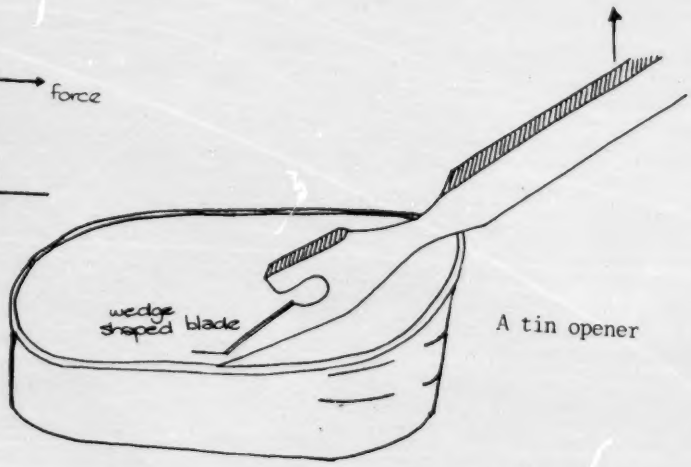
e.g. (a) striking a match

(b) any wheel is a machine which continuously reduces the force needed to overcome friction on the ground.

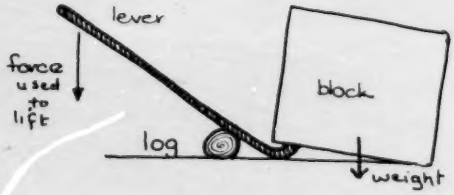
c) Here are some pictures of other household machines to discuss with the pupils. They should try to identify where they would put force in, where the pivot is and where the work is done (except for the well's windlass where they may not be able to identify the pivot).



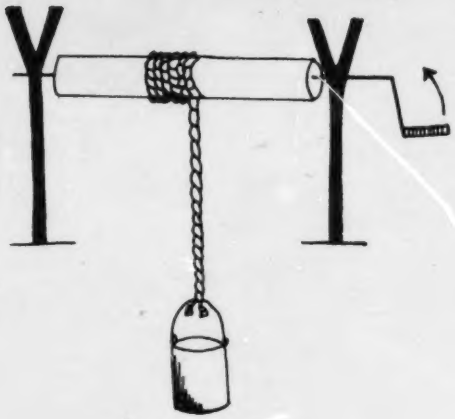
th claw on a hammer



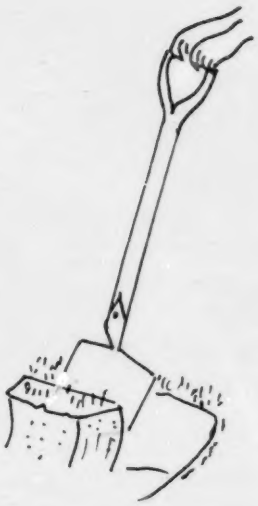
A tin opener



A crowbar



a windlass to lift water from a well



a spade

More about machines Page 40

In discussing this picture try to get pupils to work out the distance the chain being pulled by the boy moves compared with the distance the ox is lifted.

Experiment 15 Page 41 part I

Finding the weight of the Kariba battery (or any other object of similar mass). Find its mass in kg on the Zim-Sci balance and convert to weight by multiplying with the force of gravity, 10 Newtons per kilogram.

Table

Force to be overcome in lifting battery	a	N
Distance battery is lifted	b	m
Force exerted through forcemeter	c	N
Distance forcemeter moves while battery is lifted	d	m
Work done on battery (a x b)		J
Work done by muscles through force-meter (c x d)		J

Discussion

The pupils should find that slightly more work is done than appears in the lifted battery. Ask them what other hidden force needs to be overcome. The extra energy needed is used to overcome the forces of friction in bending the string and moving the pulley.

Experiment 15 Part II Page 44

The purpose of this experiment is for pupils to thoroughly explore the workings of a simple machine. The pulley system has been chosen for this explanation because it is the machine most likely to be familiar to pupils.

Assembly of the pulley system

The Zim-Sci pulley 'block' has a removable screw on which the pulleys rotate. This enables the pulleys to be changed from 1 to 2 or large to small. Before this lesson take each pulley system apart and reassemble them with only one

pulley in each pulley block. It is very instructive for pupils to compare the effect of changing the diameter of the pulleys in the system (see note after table), but to avoid unnecessary complications if this is done, make sure the pupils use the same size pulley on the top and bottom blocks.

The table of results:

the purpose of this table is to enable pupils to see at a glance the relationship done on each load lifted and the work done by the lifting force (through the forcemeter).

Table of results

Load	Pulley size	Dist. load lifted	Dist. lifting force moves	Force on load	Lifting force	Work done on load	Work done by lifting force

If time permits and the class is bright the table can be extended so that the experiment can be repeated using small pulleys top and bottom. If this is done the class should find that the lifting force still has to move twice as far as the load is lifted but more work needs to be done because of the increased friction in bending the string around the smaller pulleys.

Discussion

The pupils should notice that a little more than half the force on the load is needed to lift it. But because the distance over which this force is used is twice the distance the load is lifted, the work done when using the machine is a little more than would be used in lifting the load directly. The usefulness of the machine is in reducing the force needed. Although slightly more work must be done because of friction and the extra work needed to lift the bottom pulley block, the smaller force needed means that larger loads can be lifted by muscle force than would be possible directly.

How Powerful Are You? Page 46

It may be a good idea to revise the development of the units of force, work and energy before getting onto the units of power.

Here for your reference is a list of these concepts and the corresponding units.

Force - 'the energy agent' - the unit of force is the NEWTON . A common example of an every day force is the force of gravity. The force of gravity is approximately 10 Newtons per kilogram. Ask a child what is his or her mass. Get the class to work out the weight (force of gravity) in Newtons.

Work - Work is done when a force causes something to move. It is measured by the product of the force and the distance it moves the object. So the unit of work is the amount of work done when a force of 1 Newton is applied over a distance of 1 metre. This unit is called the Joule.

Energy - What makes things happen. When we say "some work has been done" we mean energy has been changed from one kind into one or more other kinds. So energy and work are the same thing and of course are measured in the same unit of Joules.

Power - It is very important that pupils realise that power is a measure of how quickly work can be done or how quickly energy can be changed from one form to another. The English language tends to use the word powerful to mean "having a bigger force" this is not always correct in the scientific sense.

Experiment 16 Page 46

Point out to the pupil that the muscle power they are measuring is available for only a limited time. If a pupil tried to go on working at that rate for much longer than 30 seconds he would become tired and his muscles would not generate the force required anymore.

We become 'tired' when the chemical reaction which releases the energy into our muscles stops or slows down. This can happen when the 'waste products' of the reaction accumulate in the muscles.

Make sure the chairs used are strong and safe.

Exercise 13 'Working out your power'

Name: (Farai)

Mass: (45 kg)

Force of gravity on my body = (10 x 45 = 450 newtons)

Distance lifted each step = (0,5 m)

Number of steps in 30 seconds = (20)

Therefore total distance my body is raised = (20 x 0,5 = 10 m)

Work done by me against force of gravity = (450 x 10 joules

= 4 500 joules)

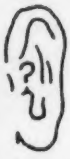
This work is done in 30 seconds

Therefore work done per second is $\left(\frac{4\ 500}{30}\ \frac{J}{s}\ \text{(watts)} = 150 \text{ watts}\right)$

N.B. These figures have been put in to illustrate how the calculation is done. Do not use these instead of actual pupil results.

- At the same time, do not allow the pupils to get lost in complicated arithmetic. If the numbers they get for their observations are awkward, point out to them that the experiment is not very accurate and so numbers can be rounded off to make the arithmetic easier, without sacrificing the purpose of the experiment.

Discussion

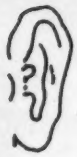


An interesting discussion can arise over the results. Are girls less powerful than boys? Are big or small pupils more powerful? The discussion is really about the concept "power to weight ratio". The power to weight ratio is important in the design of motor cars. A racing car must have a high power to weight ratio if it is to be able to accelerate rapidly.

An interesting example of a very high power to weight ratio is the ant. Ask the children if they have ever noticed ants carrying or moving things much bigger than themselves. It has been calculated that if an ant was man-size and still kept the same power to weight ratio it would be able to lift large cars!

Common Energy Convertors

This table is only intended to show the approximate values for the energy convertors listed - tractors, fires and people all vary in size!



Point out to the pupils the convertion used to express large powers.

kW = kilowatt = 1 000 watts

MW = megawatt = 1 000 000 watts

Energy chains for numbers 6 and 10

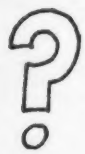
6. Farm tractor: chemical potential → heat + kinetic (the same as the motor car)

10. Kariba Power Station

Heat (from the sun) → kinetic energy (molecules of evaporated water) → gravitational potential energy (stored water in dam) → kinetic energy (falling water and turning turbines) → electrical energy.

Point out that Kariba is not only a very powerful energy source, it is also renewed each rainy season as the solar energy which energises our weather system puts more water into the dam.

How much do you know Part III



1. resistance to movement
2. Joules
3. Distance
4. forcemeter, ruler
5. any examples of levers or pulley system quoted in the text
6. easier
7. Watts - time in seconds
8. 1 Watt

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Aims of this unit H_2

To identify the principles of force, support and action in organisms.

Concept Development

Pupils first learn the purpose of skeletons in living things, then about the three main forms of support in plants, and 3 main types of skeletons in animals.

The ways in which the bones are adapted according to the medium in which an animal lives are observed.

The method by which stability is maintained in four legged animals is investigated and reference is made to the centre of mass.

Pupils find that limbs are "Animal Machines" - made of muscles which exert a force on a bone which acts as a lever. These machines effect movement.

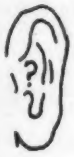
Muscles act in antagonistic pairs (as muscles can only contract). The energy used by muscles comes from food.

Lastly the protective function of various parts of the skeleton is discussed.

P

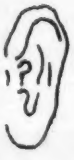
Page 2

How Gravity Affects Some Organisms



The downward pull is not so great on small organisms as on large ones. An insect or worm can be dropped quite a distance without harm - whereas a dog or man dropped from a similar height, say 2 to 3 meters can be badly hurt or even killed.

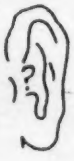
A moth or ant can hang or walk upside down holding on to a leaf, whereas if a human tried to hang that way from a tree branch, your arms and legs would tire very quickly because of the pull of gravity on the large mass.



Page 2

Support systems. Remind pupils of Unit A_2 when they saw the shells of snails and millipedes, and the bones of vertebrates.

Page 3



The model had soft jelly hard jelly, a plastic bag and a box. representing cytoplasm, nucleus membrane and cell wall (Unit E).

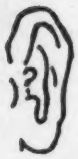
A wall made of boxes full of clay would be like a brick wall - stronger than a wall of jelly!

Experiment 1 page 3

Pupils should pick a weed or a piece of plant from outside in the sunshine.

The picked plant in the plastic bag should lose water and become wilted or flaccid. Water droplets should be seen inside the bag. This should lead to the conclusion that the water inside the cells of the plant helps keep the plant stiff ot turgid.

The wilted plants could be placed in a bucket of water overnight, and in the morning some plants may have taken up water and become turgid again. Many weeds however do not recover. Point out to the pupils that the plants in the school garden flop and their leaves wilt if they are dry. However a few hours after being watered they recover and stand up again.



Pupils should notice that small plants and seedlings use water as support, large plants - bushes and trees use wood for support.

Exercise 1 page 4

a) Write up this experiment and your own conclusion.

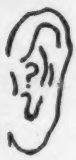
b) What are the three main forms of support in plants?

Answers: 1) Water

2) Cellulose walls

3) Woody material laid down in the cells (lignin)

Page 5



Animal Support Systems

Animals with an external skeleton were classified as invertebrates, those with an internal skeleton as vertebrates.

Invertebrates - beetle, slug, millipede, earthworm, fly.

Vertebrates - mouse, bird, lizard, frog, fish.

Page 6

Try to provide a dead dried out earthworm or slug. Pupils may notice that it is also flaccid ask the pupils to remember what is inside animal cells - they may realise that the contents of a cell include a lot of water.

Activity 1 page 6

Provide an earthworm.

The day before this activity, blow up several balloons and leave blown up overnight. Give pupils the stretched balloons. Ordinary balloons will not become big enough if filled with water through a tunnel due to the lack of pressure.

Pupils should realise that the rubber of the balloon is elastic, and the pressure of the water can stretch it out forward. The water in the balloon gives it a firm shape and supports it so that only a small area is in contact with the desk.

The balloon should move over the line drawn on the paper. A worm moves by using 2 sets of muscles. One set running in rings around the body squeezes it, forcing the internal liquid forward, then long muscles pull up the back part of the body. Pupils observed this in A_2 , but would benefit from observing it again.

Remind pupil's of the pressure changes occuring (as a result of the contracting of the muscles) within the body of the worm.

Exercise 2 page 8

Answer: A worm can squeeze the liquid in its body with its muscular skin. This pushes the water forward. By continually squeezing and relaxing it moves along.

Activity 2 page 9

Pupils can work in large groups.

This is not a very important exercise, so should be done quickly at the end of a lesson.

Quantities:-

2 sheets of newspaper per balloon

2 small plastic beakers - water

1½ " " " - flour

(one model made by you would be sufficient)

Exercise 3 page 11

1) What sort of skeleton do you think would be best for the larva of an insect?

2) Compare the skeleton of a beetle with that of a locust.

Answer

1) A hydrostatic skeleton

2) The skeleton of a beetle is heavier and stiff all over, that of a locust is only stiff over the head and chest. The long abdomen is quite soft.

page 11

Looking at vertebrate skeletons

Provide the breast bone of a chicken and show pupils the soft transparent part.

P

Activity 3 page 12

Obtain: a thin "rib bone" of a fish

2 leg bones of a chicken - one whole, one cracked open.

Some pieces of shin bone of a cow or goat

Use bones from meat, fish or chicken which has been cooked until the flesh is very soft and comes away from the bone. Scrape or scrub the bones absolutely clean. Dry well.

Pupils should look carefully at these bones.

A fish lives in water, a bird in air, a mammal on land.

A fish bone is thin, light and "bendy" or flexible.

A fish has long powerful muscles down the length of its body. It moves by lashing its body or tail back and forth against the water. It needs bones to give it shape and form attachment for muscles. They should be able to bend with the body.

A birds bone is very light and hollow. When it breaks it shows thin supporting strands of bone inside.

A mammals bone is much more solid, but also has a hole through it in many instances (limbs, ribs, vertebrae)

page 13

Chart to give pupils (blank) with examples filled in for you.

Animal	Life style	Type of bone
Fish	moves in water	thin, light, can bend
Mammal	moves on land	stiff heavy st. ng hollow
Bird	moves in air	stiff light, strong hollow

Experiment 2 page 13

Pupils should find that the masses have reduced pull on the forcemeter when the masses are in water. The force of gravity on water animals is very much less than on land animals.

Exercise 4 page 14

Answers: Whales can grow to a greater mass than land animals as the sea supports them and reduces the effect of gravity.

A hippo has a large mass, and finds it easier to live in water where its mass is reduced.

Activity 4 page 15

The tube shape withstands harder knocks than the flat shaped straw.

Tell the pupils:-

A tube gives more strength for its mass than a solid structure of the same mass. This is why bones which have to support large masses (e.g. leg bones) are hollow.

N.B. The head or ends of these bones are thick where they have to withstand other forces - friction or impact.

Activity 5 page 15

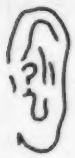
Self explanatory

Activity 6 page 16

give out scissors, paper clips, thread and the pictures (on separate stiff paper) of the buck and rat , also 5g masses

Activity 7 page 18

If you have no stikistuff, use ordinary red garden clay or black river clay.



An animal with short legs has greater stability. An animal with long legs can take longer strides when running.

Pupils should find that an animal with its feet together would not be very stable. The further apart the legs are spread out the greater the stability as the centre of mass becomes lower. However pupils may notice that when the feet are too far apart, the straws lose grip the tin sinks down as the strain on the stikistuff joints is too great. This is the reason why reptiles such as lizards and crocodiles spend as much time as they can on their stomachs.

The most satisfactory position for the legs is directly under the " joint " , or vertical.

A fish maintains stability (a) by movement (b) by the shape given it by its fins which increase the surface area of resistance to the water.

Activity 8 page 20 As in pupils guide

Activity 9 page 20

When one normally picks up a heavy object one balances out the extra mass held in front by leaning backwards (moving the body mass backwards). One cannot do this if ones back is up against the wall.

Exercise 5 page 20

As above.

Activity 10 page 21

With each step, the foot rises up at an angle, tipping the body and throwing the centre of mass forward. Thus the body is moved along.

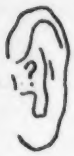
Activity 11 - as in pupils guide page 22

Methods of reducing friction page 26

Rounded shape - like ball bearings so that the surface areas in contact are very small.

Smooth surfaces, oil as a lubricant etc.

chicken bones page 26



Obtain from a chicken the 2 complete sets of pelvic girdle, thigh bone and "drumstick" bone.

The pelvic girdle is thin and has a "socket" into which the "ball" of the thigh bone fits. The other end of the thigh bone has a ridged "hinge" end. The long drumstick completes the hinge joint.

Pass the bones aroung for pupils to see the joints and the smooth cartilage on the ends.

Activity 12 page 27

Give pupils sponges.

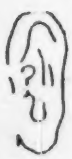
Activity 13 page 27 as in pupils guide

Experiment 3 page 28

The pupils must work in groups of 4 as 2 sponges are needed in each model. Boxes of some sort are essential for fixing the straws in place. Make a working model yourself first

Pupils can tie the thread onto the opposite corners of the sponge or make hooks out of paper clips.

A pin stuck through the straw is useful to wind or tie the other end of the thread to.



Antagonism - page 30

active opposition, opponent

Experiment 4 page 31

The pad is used so that the string will not cut into the arm.

Pupils should find the brick more difficult to lift from the wrist. Some pupils may like to try to lift 2 bricks at a time. They may find they can lift 2 bricks with the middle of the forearm, but not from the wrist.

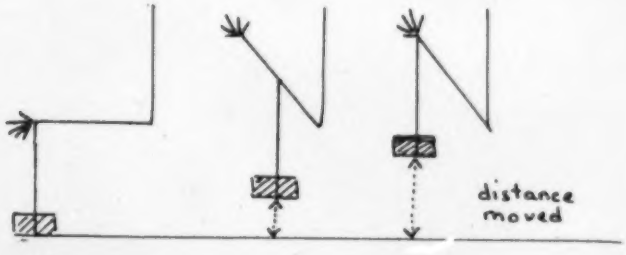
Experiment 5 page 32

Table

	Length of straw from forcemeter to masses.	Reading on forcemeter.
With 5g masses	0	
At point B	10 cm	
At point A	20 cm	

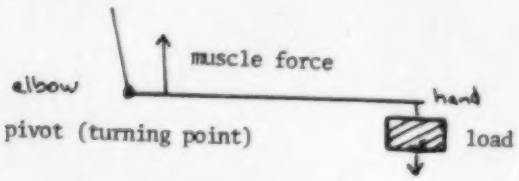
This explains why it takes more muscle force to lift a mass that is far away from the pivot (i.e. held in the hand) than a mass which is near the pivot.

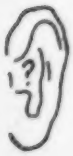
But it is more useful because you lift it further - see diagram.



The bones, joints and muscles are arranged in such a way that the bones act as levers. The muscles are attached close to the joint, which is the pivot of the bone lever, and a short contraction of the muscle gives a long distance of movement at the end of the limb.

The human arm lever





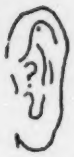
The hip or pelvic girdle of man is larger than the shoulder or pectoral girdle, as it bears most of the mass of a man.

The pectoral and pelvic girdles of a hippo are similar in size as they share the load.

Protection

1) The bones of the skull protect the brain.
2) The bones of the ribs and breastbone protect the heart, liver and lungs.
3) The holes in the vertebrae bones form a long tube which protects the spinal cord, the importance of which pupils will learn in a later unit.
4) The pelvic girdle gives some protection (at the back) to the bladder and other lower abdominal organs.

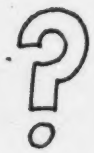
(Discuss with the pupils the other function of the ribs - that of breathing, where the muscles around the ribs pull them upward and out to increase the volume of the chest.)



Examples of insects

Examples: cricket, locust.

Note that the hardest part of the skeleton - the thorax, is connected with the "movement machine" - legs and wings.



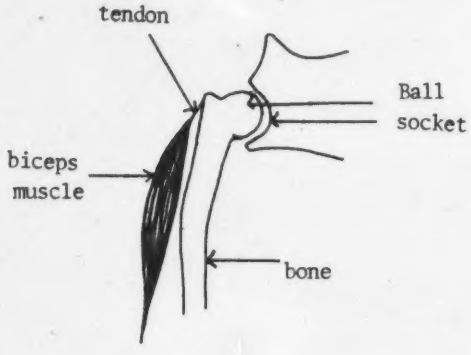
Answers to "How much do you know?"

1. Turgidity/water, cell walls, woody cells/lignin.
2. Hydrostatic, exo, endo.
3. Flaccid, turgid.
4. Friction
5. The point where the most mass is concentrated.
6. Shape, support, protection etc.
7. Move, stable.
8. Move
9. Ball socket, shoulder or hip
   hinge knee, elbow/finger
10. Synovial/lubricating, cartilage.
11. Antagonistic, biceps triceps.
12. Food.
13. Brain/eyes, heart and lungs.
    Pelvic girdle.
14. Levers machine.
15. Short long.

50.

labels should be:-

A .....Ball..... and .....socket..... joint at the shoulder.



labels should be:-

A .....a hinge..... joint at the knee.